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The Physics of Ignition Scale Hohlraums and ICF Implosions: When does size matter?[1]

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Ignition scale, high drive, hohlraums with ICF ignition capsules are four times larger than any laser-illuminated targets attempted previously. In addition, the precision in symmetry and pulse-shape / shock timing required for achieving ignition is quite stringent. This tutorial deals with the challenges presented by these issues. They are now subject to experimental study, facilitated by the capability of the National Ignition Facility (NIF) to deliver, with great precision, the very large laser energy and power needed for ignition. Given this large excursion in scale size, we disentangle here the following: What elements of our previous understanding, based on smaller scale laser experiments, might carry over smoothly to this regime, because they are scale independent? On the other hand, which might need to be refined, because small-scale experimental results were not sufficiently sensitive to issues that may become more important at NIF scale? For example, we explain how hohlraum x-ray drive has an additional component due to the large scale size, allowing Au coronal emission to play a role. Yet at the same time, we explain, on firm theoretical grounds, why certain changes/improvements in hohlraum design, based on previous results on smaller scale lasers, can be made with confidence: Size doesn't always matter. Similarly, we show how large scale-lengths may bring laser-plasma-instabilities (LPI) into more prominence. Equally important, however, is our understanding of how LPI is affected by the basic plasma conditions (T_e, n_e). A valuable knowledge base of these basics was obtained via experiments on smaller facilities. A third such example of the interplay between scale dependent and independent phenomena involves the soft-x-ray transport in the CH capsule ablator, in the presence of the higher Z dopants. These dopants are, by design, placed in the ablator in order to control higher frequency x-ray preheat. We present a computational model, (the "High Flux Model") which uses our most modern tools, that has helped explore some of these issues, and describe how it continues to be refined. We also explain why, due to the stringent precision required for ignition, we depend on our models as general guideposts to the path to ignition, and not as infallible oracles. We demonstrate how an experimental campaign, guided by those models, can, in principle, achieve the precision in implosion velocity, symmetry, shock timing and hydrodynamic instability needed for ignition.

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